IE-81-01

Luminaire Performance on Illuminated Overhead Signs

A. Maghsoudi
Senior Research Technician

F. W. Jung
Senior Research Officer

Research and Development Division

Published by:
The Policy Planning and Research Division
Ontario Ministry of Transportation and Communications
Hon. James W. Snow, Minister
H.F. Gilbert, Deputy Minister

This report may be reproduced, whole or
in part, with attribution to the Ministry

For additional copies write:
The Editor
Research and Development Branch
Ministry of Transportation and Communications
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

Printed January 1981

ABSTRACT

Considerable energy savings can be achieved by changing overhead sign illumination from mercury vapor (125 W MV) to high pressure sodium (70 W HPS) luminaires. Studies, including measurements, were carried out to show the technical viability of such a change.

The average illumination levels remain sufficiently high, and uniformity does not change significantly. Results are evaluated by comparing with various known standards, and are discussed with respect to two aspects of visibility: "attention value" and legibility of messages.

Regarding legibility, a new concept was introduced: relative local gradient of illuminance or luminance, i.e. the percentage change of these values in any direction per unit length.

Extreme values of such changes or gradients along distances of the order of letter size should interfere with legibility, and it is suggested that uniformity standards be based on this concept rather than on traditional ratios of max/min or average/min.

Reducing the distance from 2.44 m (8 ft.) to 1.83 m (6 ft.) between the three luminaires leads to acceptable results and better light utilization for HPS.

Luminance contrasts were investigated for various common color combinations of messages (letters) and background for both light sources. It was found that luminance contrasts generally increase when changing from MV to HPS luminaires.

The change from MV to HPS in sign lighting does not decrease technical performance.

CONTENTS

		Page
1/	INTRODUCTION	1
2/	TOWARDS INNOVATIVE RELEVANT STANDARDS AND PARAMETERS	2
3/	TESTING ARRANGEMENT	5
4/	MEASUREMENTS	8
5/	ACCURACY OF MEASUREMENTS	10
6/	EXPERIMENTAL RESULTS	11
7/	EVALUATION OF UNIFORMITY	19
8/	CONCLUSIONS AND RECOMMENDATIONS	24
9/	REFERENCES	26
	APPENDIX A	
	Detailed Drawing of Sign Board Installation	27
	APPENDIX B	
	Example Computer Output of Results and Supplementary Tables	29
	LIST OF FIGURES	33

1/ INTRODUCTION

Recent countrywide concerns for energy saving are about to bring many technical changes in areas of significant energy consumption. To contribute to this major issue, highway engineers and technologists in the Ontario Ministry of Transportation and Communications have been studying possible alternatives reducing energy consumption without affecting the efficiency and safety of traffic movement on roads and highways.

Overhead sign illumination is an area of significant energy consumption. A project was sponsored by the electrical Design Section of MTC Head Office, in conjunction with Maintenance Branch, asking Research and Development to carry out a series of studies on technical modifications of sign lighting.

In the past, overhead signs were illuminated with fluorescent lamps or mercury vapor type luminaires. The 125 watt mercury vapor luminaires, with ballast losses, consume 170 watts per unit. The questions were, "Can this consumption of energy be reduced by using 70 watt high pressure sodium luminaires instead, which consume 91 watts per unit, including ballast losses?" and "What are the effects on sign detection and legibility?"

High pressure sodium luminaires have higher initial lamp costs than the presently used mercury vapor luminaires, but in the long run, could prove to be more economical with regard to lower energy consumption, which ultimately means lower maintenance costs. The exact economic analysis is outside the scope of this paper.

On the other hand, different types of sign sheeting material perform differently when illuminated with different types of luminaires, and this introduces some complexity in the selection of both sign materials and suitable luminaires.

The purpose of this project is to study the performance of high pressure sodium luminaires compared with mercury vapor types, and to select a proper luminaire type and arrangement to be used with various sign sheeting materials.

2/ TOWARDS INNOVATIVE RELEVANT STANDARDS AND PARAMETERS

The past and present conventional way of setting standards for illuminated or floodlighted signs is based on illuminance (lux or foot-candle). First, the sign must have sufficient "attention value" or "target value" (1), which means it must be large enough, and have sufficient brightness, depending on the ambient light of the surroundings. Secondly, the message (lettering or otherwise) of the sign must be legible in the short time of passing by. All this is related to letter contrast, shape, size, uniformity of illuminance, avoidance of glare and excessive brightness, locally or over the whole sign. In short, the over-all color and luminance of the sign is important for its "attention value", whereas color and luminance contrast between letters and their background area on the sign is important for "legibility". Simple standards of illuminance, which reflect some of the aforementioned conditions, are presented in the following table of recommended minimum values (2).

Average Reflectivity	Recommended levels		Uniformity min/max
	Bright Surrounding	Dark Surrounding	
Low	1000 lux	500 lux	1 : 4
High	500 lux	200 lux	1 : 4

More recently, recommended uniformity values have been lowered to 1:6 (3). Provided that two classes of reflectivity and surroundings are acceptable, the sign "attention value" is well taken care of. However, simple guidance values of min/max ratios for uniformity do not assure "legibility". There may be interference with legibility by extreme low lux values or very bright spots (usually not both) pertaining to similar uniformity values.

The specifications of our Ministry of Transportation and Communications (4) try to take care of those two visibility problems by specifying minimum and maximum initial values of illuminance,

50 lux and 350 lux, which implies a uniformity ratio of 1:7. These values, comparing them with the IES-based table above, would correspond to dark surrounding and medium reflectivity without discriminating by these terms any further.

The British standards specify similar guidance values in terms of luminance (ft-L or cd/m2) (5); in particular, the following maintained values are recommended:

Minimum mean luminance	35 cd/m2
Luminance	500 cd/m2
Minimum luminance, general	20 cd/m2
signs > 2.5 m, at extremities	7 cd/m2
Luminance ratio (min/max)	1:10

Ian Lewis (1) and D.T. Leigh (5) have suggested an additional criterion for some lighting, namely luminance gradient, i.e. change of luminance per unit length (in any direction across the sign), disregarding letter or color boundaries. This innovative concept has been applied by the authors with some modifications.

Clearly, luminance gradients must be a parameter closely related to legibility of sign messages, since steep gradients must disturb color and brightness patterns of letters or other messages. However, comparison of such values for different levels of illumination can be deceiving. The authors found that such comparison is viable when luminance gradients are normalized, i.e. when they are divided by the luminance measured at the point as the gradient.

Further, this concept can be applied with much less difficulty for illuminance (lux). In other words, the following concepts of performance evaluation are introduced.

Relative gradient of illuminance: $\left(\frac{dE}{ds}\right)\Big/_{E}$

Relative gradient of luminance: $\left(\frac{dL}{ds}\right)\Big/_{L}$

Maxima and averages of these quantities can be established from the measured values of E and L at grid points on the sign board.

Another useful parameter which should be more clearly defined is luminance contrast. Sign visibility depends on both luminance contrast and color contrast. The standard photometer used by the authors can only measure luminance contrast; color contrast is an additional "bonus". However, there seems to be some confusion on how contrast should be defined for comparative measurements. The authors, contrary to other definitions, found in literature (2), (6), (7), (8), have defined luminance contrast as follows:

$$C = \frac{2\,|L_O - L_B|}{L_O + L_B}$$

where: L_O = object luminance

L_B = background luminance

$|L_O - L_B|$ = absolute value of luminance difference, numerator

$\frac{L_O + L_B}{2}$ = average of L_O and L_B denominator

This definition is especially suited for contrasts between large letters and their background, or between large signs (object) and the surrounding ambient light (background). The definition yields normalized values between C = 0 for no contrast to C = 2, maximum contrast (for L_B or L_O being zero).

3/ TESTING ARRANGEMENT

3.1/ Simulated Overhead Sign Installation

An overhead sign structure of 2.74 m by 6.10 m (9' by 20'), was simulated in a convenient area, as explained below, with the possibility of elimination of outside light interference. The installation is illustrated in Figure 1.

a) The full size structure of the luminaire installation is built according to the Ministry's present specifications (refer to Figure A-1 and A-2 Appendix A).

b) The lighting system is a combination of three luminaires with adjustable angles of light direction and with variable arrangement of horizontal distance between them. There is, however, a constant distance from the sign board as shown in Figure 1.

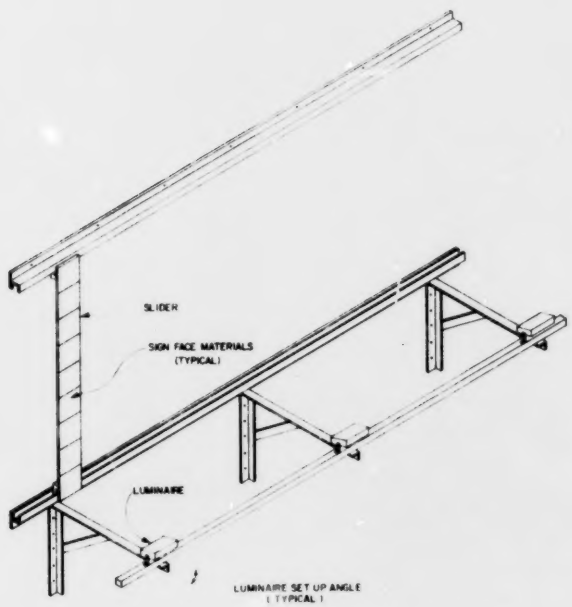


Figure 1/ Installation for Overhead Sign Simulation

c) The sign is simulated by a 0.305 m by 2.74 m (1' by 9') sliding board carrying nine vertically arranged square plates of sign sheeting materials. This sliding board can be moved

along the structure and positioned anywhere between the left and right ends of the rails. The sliding board is built in this way to make investigations more practical. It allows for nine different sign materials to be studied simultaneously by arranging plates of different colors or types of materials.

d) The luminaires used for this investigation were:

I) Mercury vapor type luminaire, 125 W Lamp, MEF - 10 - 125 - MTC, Powerlite Cat. 1975, Wattage including ballast losses: 170 W, 60 Hz. Figure 2a.

II) High pressure sodium type luminaire, 70 W Lamp, LXF - 10 - 70 - MTC, Sylvania Outdoor Lighting Cat. 1978, Wattage including ballast losses: 91 W, 60 Hz. Figure 2b.

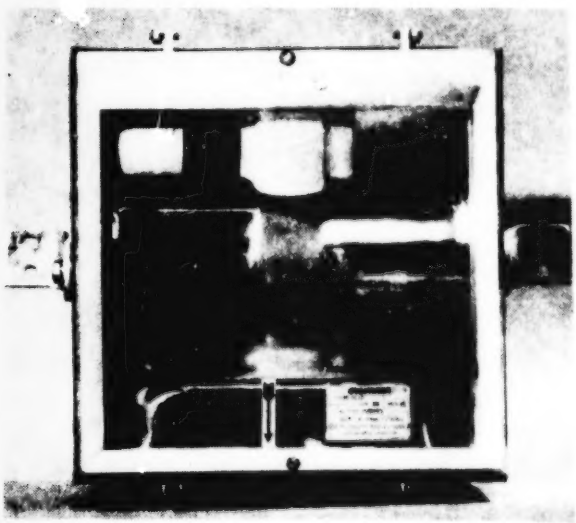


Figure 2a/
H.P.S. Luminaire

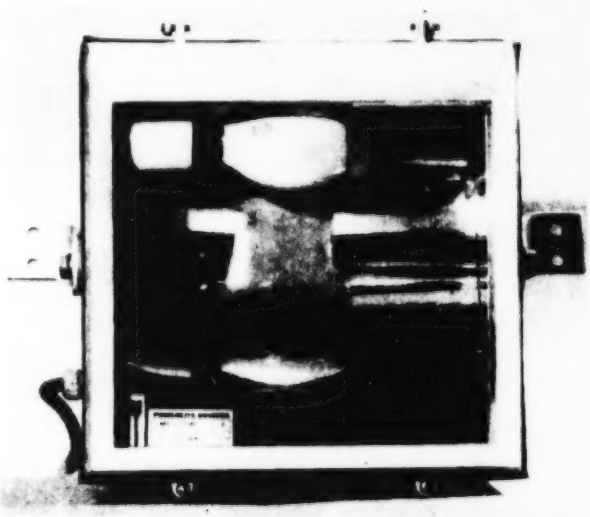


Figure 2b/
Mercury Vapor Luminaire

3.2/ Measuring Apparatus

Two different measuring devices, as shown in Figures 3 and 4 have been used in this investigation.

a) A photometer of Model DPMT-2CC operating as a simple light meter to measure illuminance (lux) along the sign board surface, Figure 3.

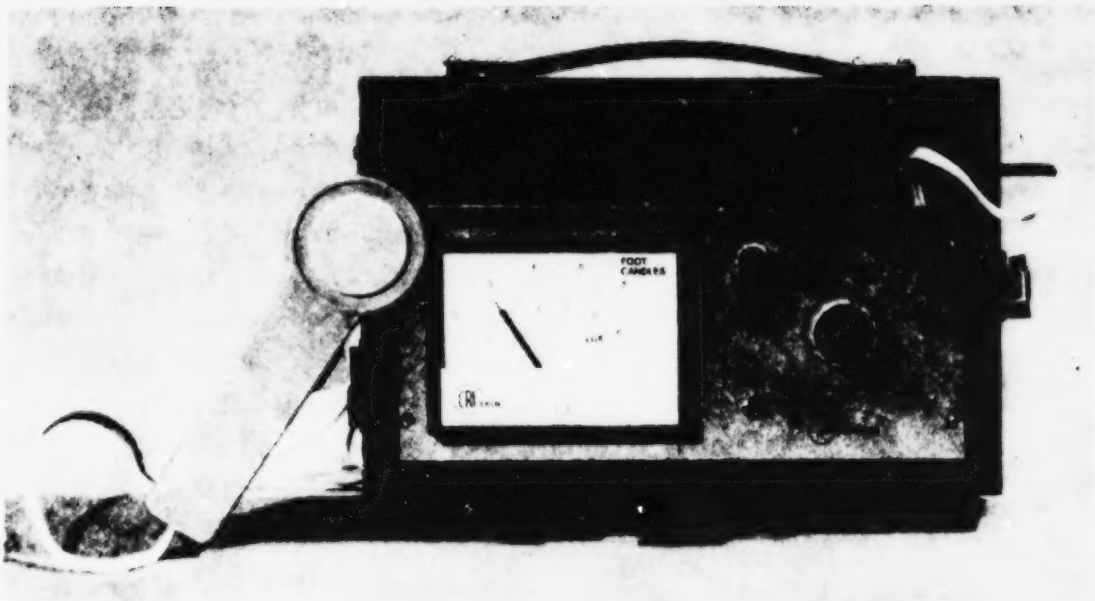


Figure 3/ Photometer, Illuminance Measuring Device

b) Spectra Prichard Photometer, a relatively complex optic-electronic instrument for luminance measurement, was used to evaluate the different types of sign sheeting material performance illuminated by the two types of luminaires, Figure 4.

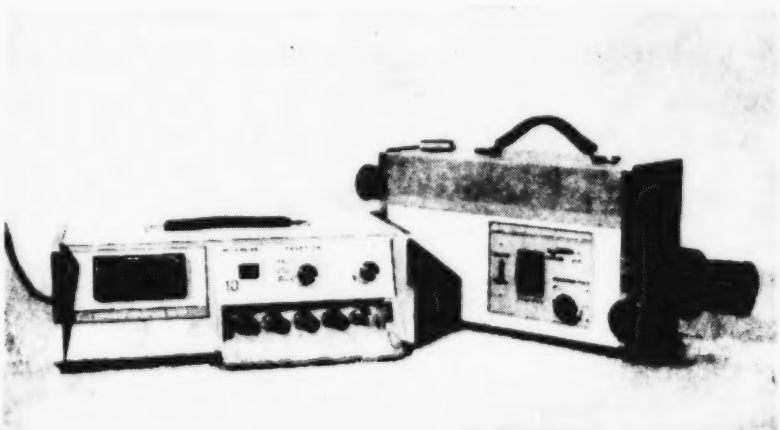


Figure 4/ Spectra Prichard Photometer, Luminance Measuring Device

4/ MEASUREMENTS

4.1/ Illuminance Measurements

As mentioned in paragraph 3.2/a, a photo-cell lightmeter has been used to measure the illuminance at grid points of a simulated sign. The measurements were carried out for 125 watt mercury vapor type luminaires and 70 watt high pressure sodium luminaires with the following luminaire arrangements:

a) Luminaires set up with 2.44 m, (8') center to center distance, with horizontal angles of 10 degrees.
b) Luminaires set up with 1.83 m, (6') center to center distance, with horizontal angles of 10 degrees.
c) The same arrangement as in a & b but with horizontal angles of zero degrees.

4.2/ Luminance Measurements

As indicated in paragraph 3.2/b, a Spectra Prichard Photometer was used for the luminance measurements of sign sheeting materials. The instrument was set-up as shown in Figure 5. The viewing angle, at the lower edge of the sign board was chosen to about 1°D, corresponding to the maximum car distance of 244 m (800 ft.), as in Figure 1 of Reference (10). In this way the maximum possible effect of glare from the lower portion of the sign towards the driver's eyes could be studied.

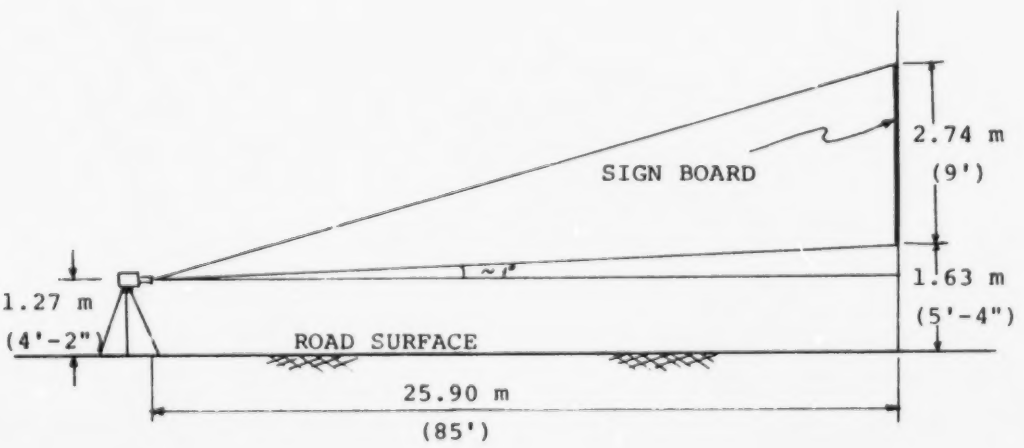


Figure 5/ Instrument Arrangement for Luminance Measurement

The factorial design of the testing experiment outlined above has been summarized in Table 1.

Table 1/ Factorial Design of Experiment

Type of Studies	Luminaire set-up Angle	high pressure sodium		mercury vapor	
		Luminaire distance (centre to centre)			
		1.829 m (6')	2.438 m (8')	1.829 m (6')	2.438 m (8')
Illuminance	10°	+	+	+	+
	0°	+	+	+	+
Luminance	10°	+	+	+	-
	0°	-	-	-	-

Legend: + cases where a set of measurements was taken
- cases where no measurements were taken

5/ ACCURACY OF MEASUREMENTS

To minimize the effect of voltage variation, the measurements were carried out at weekends when other extensive electrical equipment was not in use.

However, variations of ±15 percent may be expected in this type of lighting measurement when carried out on different days.

6/ EXPERIMENTAL RESULTS

6.1/ Illuminance Measurements

Illuminance measurements were carried out as discussed under 4.1/. The results are summerized in Table 2, supplemented by print-out of light distribution patterns which are produced using a special computer program. Refer to Figure 6 and 7 as examples. Other examples of computer output for determining the Illuminance or Luminance characteristics are given in Appendix B of this report.

The objective was to compare the performance of the two light sources, 70 W HPS and 125 W mercury vapor, for various angles and luminaire distances.

A comparison of Figure 6 and 7 reveals that there is better, i.e. more uniform light distri' ution for 10° angle. Observe the wider dark strips at the bottom and top of the simulated sign board, Figure 7, illuminated with 0° angle. This observation corresponds to a large difference in uniformity ratios in the last two columns of Table 2. Similar differences can also be observed in the columns for 10° and 0° of all other cases. Going from 10° to 0° the increase in Max/Min uniformity ration, for instance, is of the order of 3 to 4. Therefore, the 10° angle can be regarded as superior for cases in Table 1 and further discussion can be confined to the cases of 10° angle. Figures 6 and 8 show distribution patterns for mercury vapor luminaires (for 10° angle) for 2.44 m (8') and 1.83 m (6') distance of luminaires respectively. Figures 9 and 10 are the corresponding diagrams of light distribution for HPS. Numerical values for these case measurements are presented in Table 2.

Table: 2 Summary of the Illuminance Measurement Results on Mercury Vapor Type and High Pressure Sodium Luminaires

Luminaire Type	70 W. High Pressure Sodium				125 W. Mercury Vapor			
Luminaire Distance	1.829 m, (6')C. to C		2.438 m, (8') C. to C		1.829 m, (6')C. to C		2.438 m, (8')C. to C	
Luminaire set-up Angle	10°	0°	10°	0°	10°	0°	10°	0°
Avg. Illuminance, "Lux"	220.7	173.0	202.9	147.0	283.7	223.9	255.1	200.1
Max. Illuminance, "Lux"	376.7	317.5	355.2	258.3	516.7	430.6	452.1	366.0
Min. Illuminance, "Lux"	80.7	21.5	86.1	21.5	86.1	21.5	123.8	32.3
Avg./Min. Uniformity	2.73	8.03	2.36	6.83	3.29	10.40	2.06	6.20
Max./Min. Uniformity	4.67	14.75	4.12	12.00	6.00	20.00	3.65	11.33
Gradient Uniformity	0.488	0.734	0.428	0.683	0.434	0.634	0.410	0.587

*Gradient Uniformity expressed as Ratio of Average Gradient to Average Illuminance

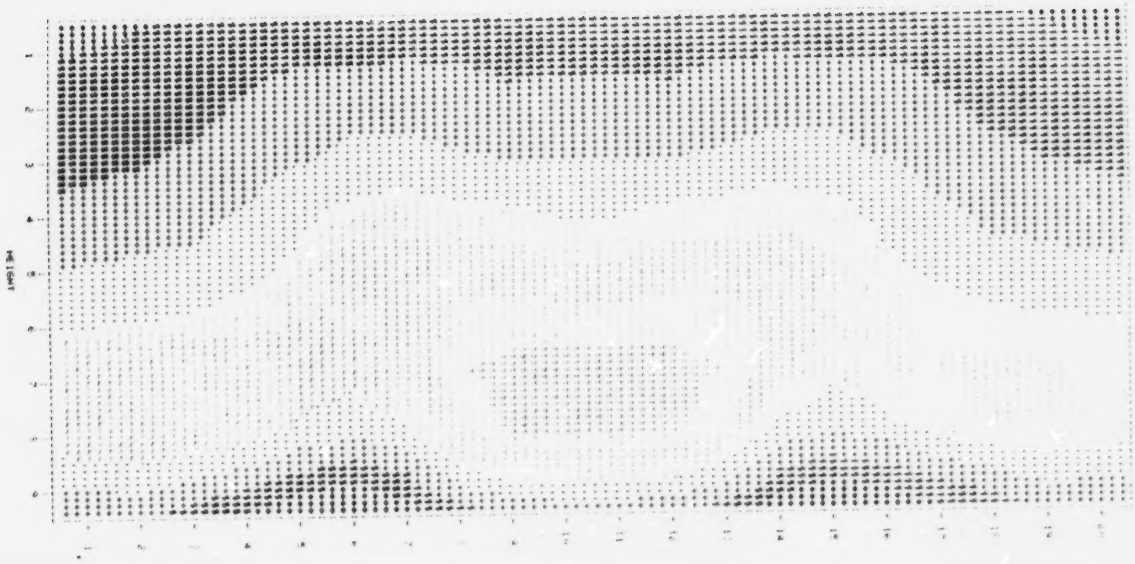


FIGURE 6: Light Distribution Pattern for 125 W M.V. Luminaires with 2.43 m (8') c.to c.Distance and 10° Angle

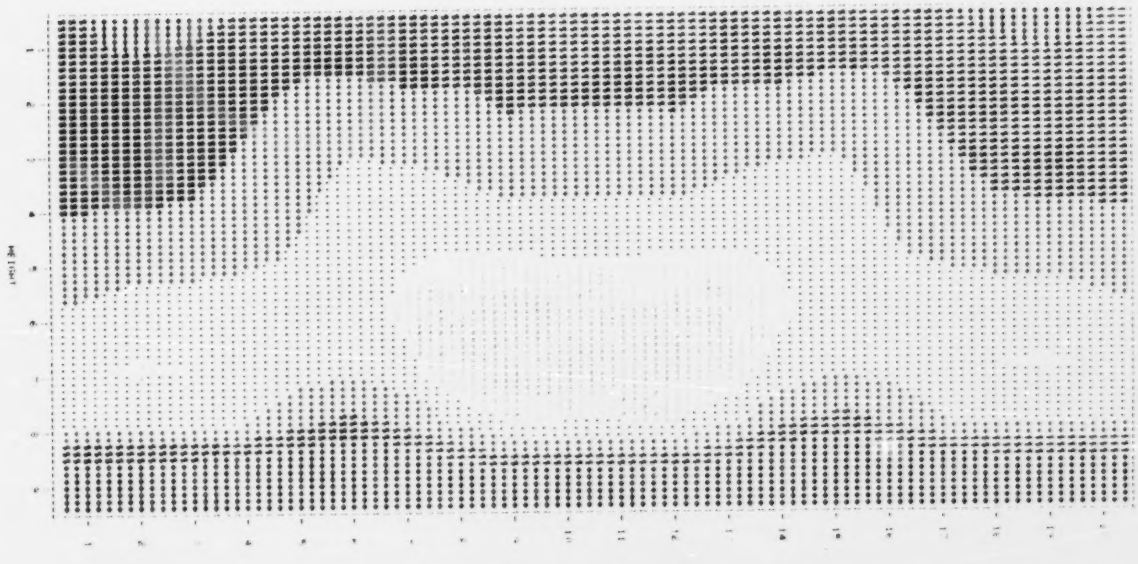


FIGURE 7: Light Distribution Pattern for 125 W M.V. Luminaires with 2.43 m (8') c. to c. Distance and 0° Angle.

LEGEND : (ILLUMINANCE IN LUX)

◆ = 100.00 $ = 150.00 + = 200.00 . = 250.00 ~ = 300.00 " = 350.00

^ = 400.00 ? = 450.00 ; = 500.00 0 = 550.00 # = 600.00 C = 700.00

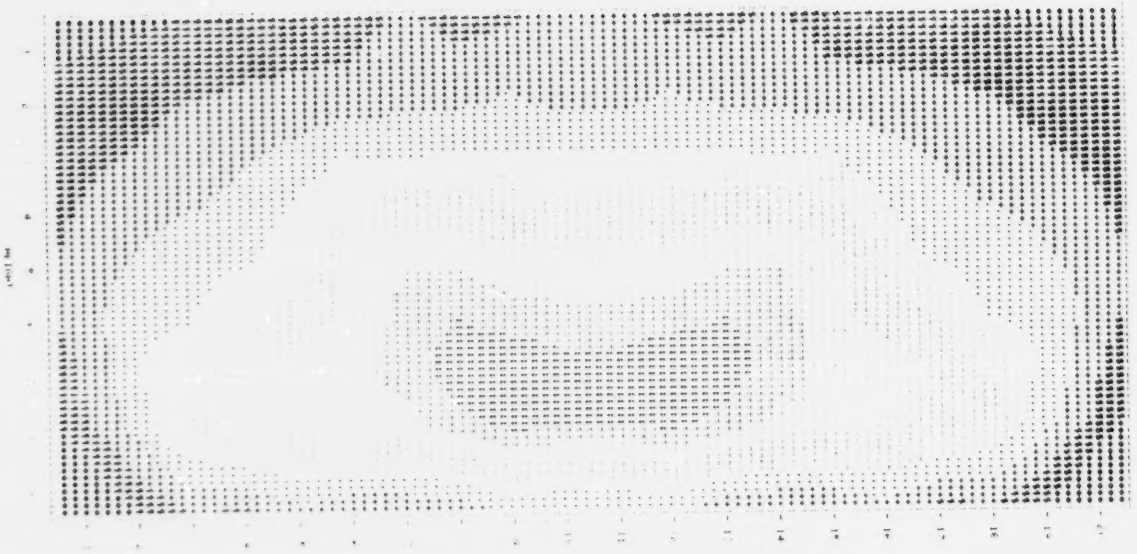


FIGURE 8: Light Distribution Pattern for 125 W M.V. Luminaires with 1.829 m (6') c. to c. Distance and 10° Angle.

LEGEND : (ILLUMINANCE IN LUX)

• = 100.00 $ = 150.00 + = 200.00 . = 250.00 ~ = 300.00 " = 350.00

~ = 400.00 ? = 450.00 ; = 500.00 0 = 550.00 # = 600.00 C = 700.00

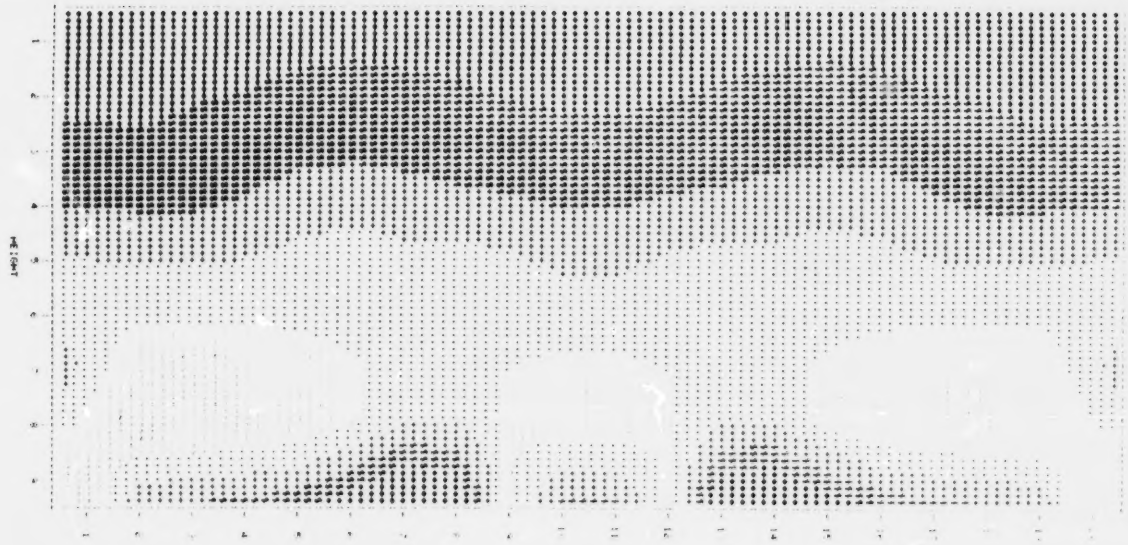


FIGURE 9: Light Distribution Pattern for 70 W H.P.S. Luminaires with 2.43 m (8') c. to c. Distance and 10° Angle.

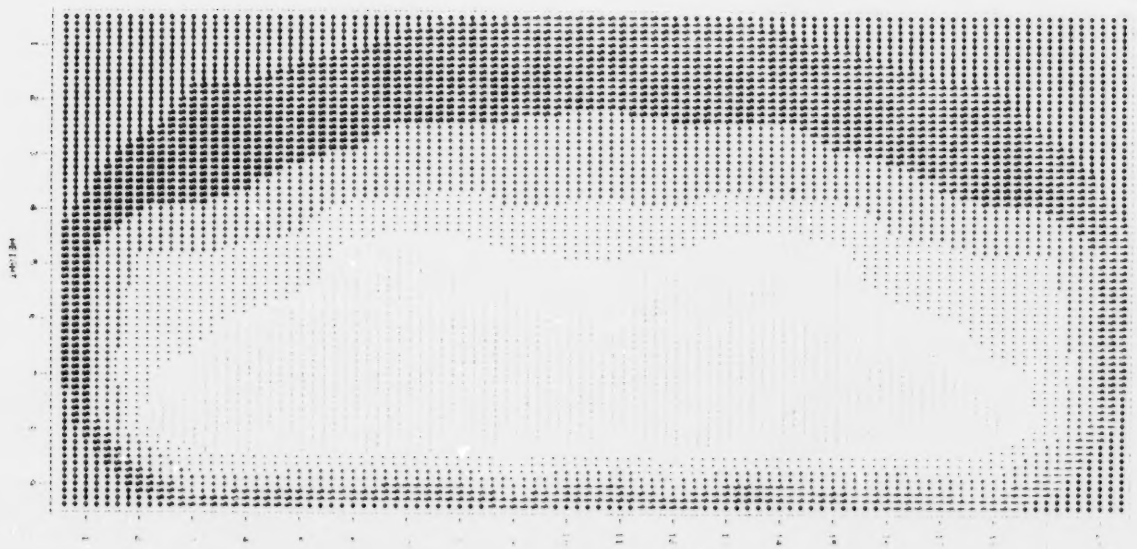


FIGURE 10: Light Distribution Pattern for 70 W H.P.S. Luminaires with 1.829 m (6') c. to c. Distance and 10° Angle.

LEGEND : (ILLUMINANCE IN LUX)

◆ = 100.00 $ = 150.00 + = 200.00 . = 250.00 ^ = 300.00 " = 350.00

^ = 400.00 ? = 450.00 ‡ = 500.00 0 = 550.00 # = 600.00 C = 700.00

For both light sources, HPS and mercury vapor, the 1.83 m (6') luminaire distance leads to slightly higher average and maximum values for illuminance than the 2.44 m (8') distance. This is contrary to the minimum values, which are all lower for 1.83 m (6') distance.

In the case of mercury vapor luminaires, when changing their distance from 2.44 m (8') to 1.83 m (6') there is considerable deterioration of uniformity (Table 1). In the case of HPS there is only a slight change (deterioration) of uniformity, i.e. the 2.44 m (8') distance is only slightly more uniform than the 1.83 m (6') distance for HPS.

Both luminaire types utilize the light output better at 1.83 m (6') than at 2.44 m (8') distance, however, the corner areas of the sign are darker for the 1.83 m (6') arrangement.

The following comparison with standards is presented.

a) MTC - Standards (4)

		Measured Initial Values (10° Angle) 70 W HPS		125 W MV	
	Standard Initial Values	1.83 m	2.44 m	1.83 m	2.44 m
maximum lx	350	377	355	517	452
minimum lx	50	80	86	86	124
uniformity min/max	1 : 7	1 : 4.7	1 : 4.1	1 : 6	1 : 3.7

All light sources arranged with the two selected distances comply very well with MTC standards.

b) IES - Standards for "dark" surrounding (2).

	Standard Initial Values	Measured Initial Values (10° Angle) 70 W HPS 1.83 m	70 W HPS 2.44 m	125 W MV 1.83 m	125 W MV 2.44 m
average lx	200	221	203	284	255
uniformity min/max	1 : 4	1 : 4.7	1 : 4.1	1 : 6	1 : 3.7

All cases comply fairly well, except for the uniformity from the 125 W mercury vapor luminaire at 1.83 m (6') distance.

6.2/ Luminance Measurements

a) Evaluation of measurement for glossy white sign material: The result of luminance measurements on different color plates of sign materials are presented in Table 3. Both types of luminaires were investigated for 10° angle and 1.83 m (6') distance only. The first line of Table 3 can be compared with British Standards, given in Reference (5). For white plates of the sign and using a maintenance or light loss factor of 0.64, the following table is presented.

	B.S. - Standard	Measured Initial Values 70 W HPS (Refer to Table 3)	125 W HPS (Refer to Table 3)
Minimum mean luminance cd/m^2	> 35	55 x 0.64 = 35	67 x 0.64 = 43
Maximum luminance (initial) cd/m^2	< 500	98	129
Minimum luminance cd/m^2	(> 10) (> 7)	22.3 x 0.64 = 14.3	28.2 x 0.64 = 18.1
Luminance ratio, min/max	> 1: 10	1 : 4.4	1 : 4.6

The luminance measurements on the glossy white plates comply with British Standards for both types of luminaires, but with much superior uniformities. However, luminance values may change with different viewing angles than chosen by the authors (1° at the lower edge of the sign), so that average luminance may be slightly lower. This should be no problem with regard to sign legibility because of the excellent uniformity.

b) Luminance contrast of sign materials of different colors:
A special computer program was developed and used to calculate luminance contrasts at the grid points of the simulated sign board for different combinations of message/background colors, based on the luminance measurements of various colors of sign material. "Contrast" was defined in accordance with Section 2 of this report, on page 4, and varies in a range from zero to two for no contrast and for maximum contrast respectively. The results of this investigation have been compiled in Table 4. The table shows the minimum contrasts found by screening all the points across the sign board. The values in the upper shaded areas of each box of the table pertain to illumination by 70 W HPS, and the lower, non-shaded values correspond to illumiination by 125 W mercury vapor. Luminance contrast values for the most useful color combinations are found in the heavily framed part of the table. It can be seen that HPS illumination produces generally higher luminance contrast values compared with mercury vapor illumination, except for "black on white" for which the values are about equal.

For both light sources, the following colour combinations lead to very good luminance contrasts:
1) white: with black, blue and green, for E.G. and H.I.
2) orange: with black and blue - E.G.
Combining orange with blue (H.I.) and with green (E.G. and H.I.) leads to good contrast only under mercury vapour light, whereas the contrast is inferior under HPS. These combinations cannot be recommended.

Table: 3 SUMMARY OF THE LUMINANCE MEASUREMENT RESULTS

FOR: "1.829 m, (6') C. to C. and 10° Luminaire Angle"

Luminaire Type	70 W. High Pressure Sodium						125 W. Mercury Vapor					
Luminance Characteristic	Luminance Cd/m²			Uniformity			Luminance Cd/m²			Uniformity		
Material Colour & Type	Avg.	Max.	Min.	Avg. / Min.	Max. / Min.	Grad-ient	Avg.	Max.	Min.	Avg. / Min.	Max. / Min.	Grad-ient
WHITE (Glass)	55.04	97.50	22.30	2.47	4.37	0.408	66.54	129.10	28.20	2.36	4.58	0.395
BLACK (Glass)	0.47	0.86	0.23	2.03	3.74	0.413	0.48	1.08	0.20	2.39	5.40	0.373
Green (E.G.)*	1.14	2.79	0.32	3.57	8.72	0.580	2.25	6.63	0.72	3.13	9.21	0.557
Green (H.I.)**	1.10	2.57	0.35	3.15	7.34	0.537	-	-	-	-	-	-
BLUE (E.G.)	0.66	1.64	0.26	2.55	6.31	0.514	-	-	-	-	-	-
BLUE (H.I.)	1.06	2.06	0.36	2.94	5.72	0.486	-	-	-	-	-	-
ORANGE (H.I.)	25.93	45.20	10.40	2.49	4.35	0.408	-	-	-	-	-	-

* : Engineering grade

** : High intensity

Table: 4 Summary of Minimum Contrast Level along the simulated signboard for different combinations of Message & Background Colours

when Illuminated with 70 W. H.P.S. Luminaires

when Illuminated with 125 W. Mercury Luminaires

Message, Background (Colour & Type)	WHITE	BLACK	BLUE (E.G.)	BLUE (H.I.)	GREEN (E.G.)	GREEN (H.I.)
BLACK	1.95* / 1.97					
BLUE (E.G.) *	1.93 / 1.92	- / 0.06				
BLUE (H.I.) **	1.91 / 1.86	0.42 / 1.01	0.18 / 0.53			
GREEN (E.G.)	1.88 / 1.76	0.33 / 1.12	0.17 / 0.97	- / 1.15		
GREEN (H.I.)	1.89 / 1.71	0.40 / 1.38	0.16 / 1.18	- / 0.55	- / 0.08	
ORANGE (H.I.)	0.68 / 1.16	1.90 / 1.87	1.86 / 1.72	1.82 / 1.51	1.76 / 1.23	1.78 / 1.10

* Engineering Grade

** High Intensity

7/ EVALUATION OF UNIFORMITY

Usually uniformity is evaluated by calculating two parameters, namely maximum to minimum ratio and average to minimum ratio. The first requirement for fair comparison is that the underlying values are measured on a system of grid points of the same density on the sign board. In other words, grid points for such measurements must be specified, such as in terms of squares of 305 mm (or 12 inches), as the authors have done. In spite of this, the aforementioned ratios could distort the evaluation of uniformity because of low localised minimum values of the edges. They could unduly increase the ratios for sign boards with otherwise good uniformity, since low values at the very edges or corners are of minor importance for reading messages and letters located away from the edges.

Legibility of letters or symbols must depend on a locally established parameter, and, as indicated before, it is proposed to use a value of normalised gradient. For illuminance, such a relative gradient is defined as follows:

$$\frac{E}{E \times \Delta S} = \frac{E_{i+1} - E_i}{1/2(E_i+E_{i+1}) \times \Delta S_i}$$

compare with $\left(\frac{dE}{ds}\right) \Big/ E$, page 3

where:

$E = |E_{i+1} - E_i|$ = absolute difference of illuminance between two adjacent points (i) and (i + 1) in any direction (in practical terms: vertical, horizontal and diagonal)

$E = 1/2(E_i + E_{i+1})$ = arithmetic average of illuminance at adjacent points (i) and (i + 1)

$S = \Delta S_i$ = distance of grid points of measurement (again vertical, horizontal or diagonal)

It is stipulated that high values of this normalized gradient interfere with legibility of letters, numbers, or other symbols.

An overall indication of legibility would be the average of all such relative gradients across the (simulated) sign board. The relative gradient values for all cases of illumination are presented on the bottom line of Table 2.

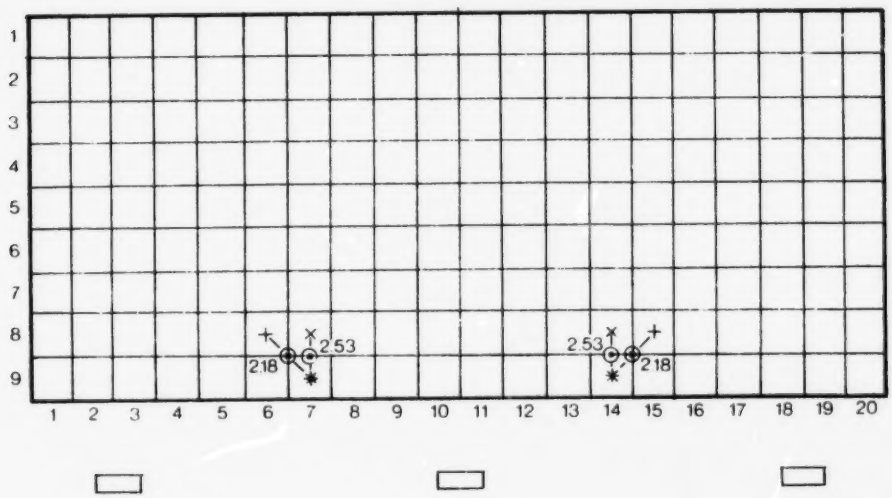
It should be noted that all parameters for evaluating uniformity are subject to changes when using luminance instead of illuminance. However, it can be demonstrated that such changes are a great deal smaller for relative gradient than the max/min or average/min ratios.

Figures 11 and 12 present the magnitude, direction, and location of maximum normalised gradients of illuminance on the simulated sign board, and average values of gradients from all grid points on the board are also shown. All gradient values were calculated and selected from tabulated illuminance values listed for each grid point (as shown in Figure B4, Appendix B, for instance). The gradient calculations were based on differences of illuminances taken in all eight directions, horizontal, vertical, and 45°-diagonal.

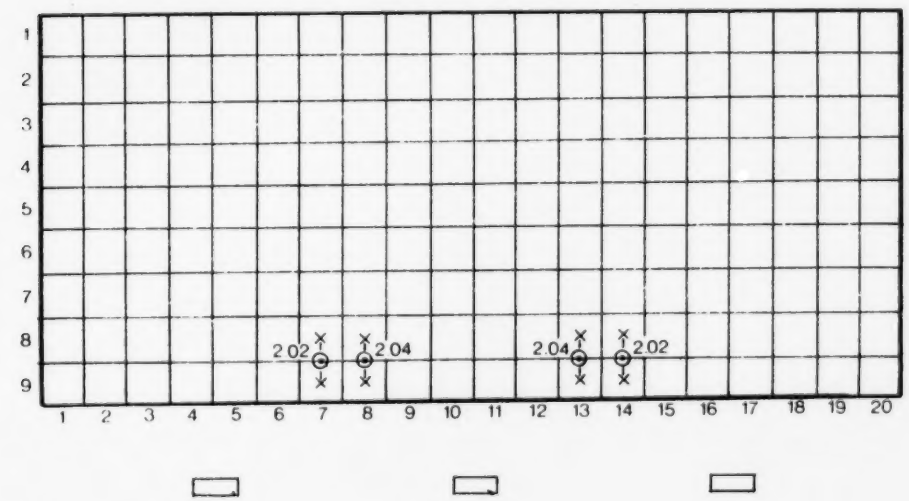
The values calculated represent the relative change of illuminance per unit length. For instance, in Figure 11, the largest value of 2.53 means that, at this location, there is a vertical maximum rate of change of 253% per metre, or of 25.3% per one dm, or of about 75% per foot (30.5 cm). The reference units of one dm and 30.5 cm (ft.) are more closely related to letter size, and the corresponding percentage changes of illuminance must be judged in terms of the legibility of such letters.

The changes are maxima and have been found on the board by scanning. (Figures 11 and 12). Moreover, these maxima occur at the very bottom of the simulated boards, and messages or letters are usually above these points. It is believed that a relative change in illuminance of such magnitude (2.53 or less) does not reduce legibility significantly.

Figure 11/ Location of the Points with Maximum Illuminance Gradients and Magnitude of the Related Normalized Gradient Uniformity for H.P.S.

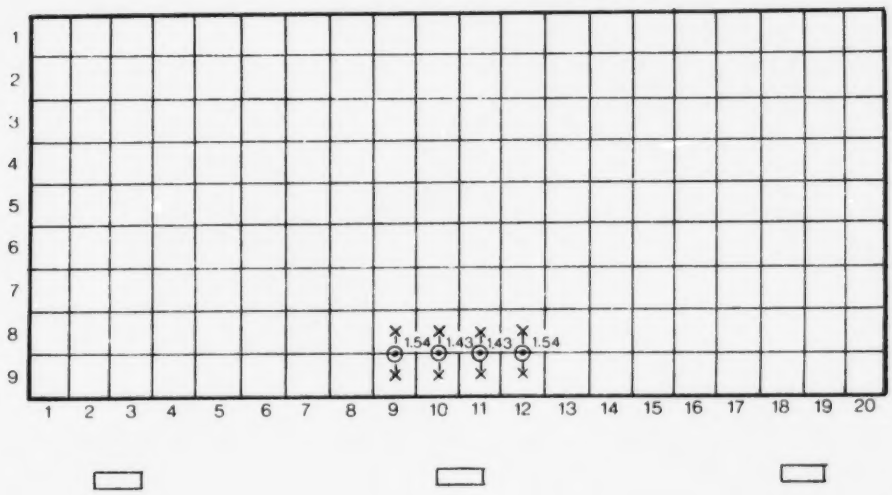


Luminaires with 2.44 m, (8') C. to C. distance and 10° Angle
Average Normalized Gradient uniformity: 0.410

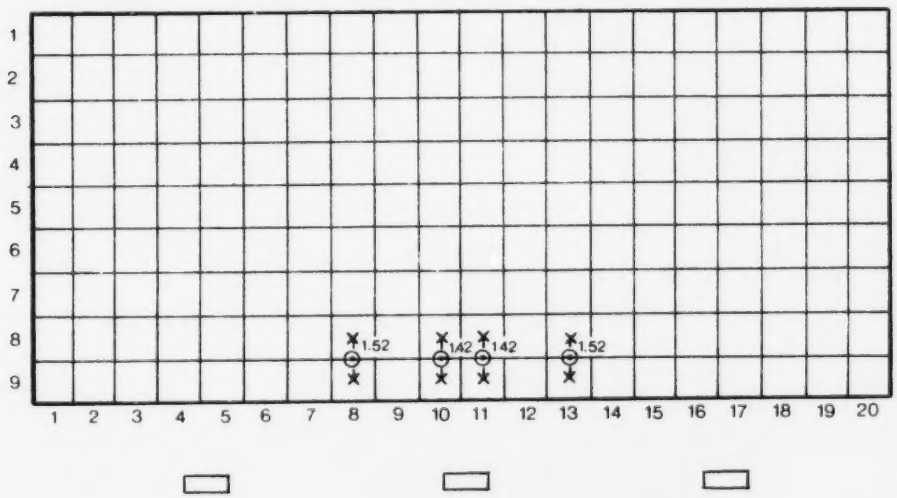


Luminaires with 1.83 m, (6') C. to C. distance and 10° Angle
Average Normalized Gradient uniformity: 0.434

Figure 12/ Location of the Points with Maximum Illuminance Gradients and Magnitude of the Related Normalized Gradient Uniformity for Mercury Vapor



Luminaires with 2.44 m, (8') C. to C. distance and 10° Angle
Average Normalized Gradient uniformity: 0.428



Luminaires with 1.83 m, (6') C. to C. distance and 10° Angle
Average Normalized Gradient uniformity: 0.488

As shown on Figures 11 and 12, the maximum relative gradients remain almost the same for both distances, 1.83 m (6') and 2.44 m (8') for both light sources.

The values for the mercury vapor (MV) luminaires are lower than those for the HPS luminaires, which means slightly better local uniformity in the case of MV. However, there is much less change for the average of all relative gradients, which are also listed in Figures 11 and 12. As the maxima are located close to the lower edge of the simulated sign board, the difference in these maximum values for the two light sources is irrelevant with regard to legibility of letters or messages. In view of this, the average values listed are probably more indicative.

8/ CONCLUSIONS AND RECOMMENDATIONS

1. For the luminaires investigated, a setting angle of about 10° can be recommended. The authors feel that an angle slightly less, between 7° to <10°, could eventually lead to marginally better results.

2. The Mercury Vapor luminaires perform better with 2.44 m (8') distance, because of superior uniformity (37% larger ratio of max./min.), which is more important than a slight (10%) increase in average level at 1.83 m (6') distance (Table 2).

3. The High Pressure Sodium luminaires perform about equally well for both distances. There is a slightly (9%) higher average illuminance level for the shorter distance of 1.83 m (6') but about 12% lower uniformity (max/min). Here the authors feel that the higher average level is more important than slightly better uniformity. Comparison of light distribution patterns for H.P.S. luminaires indicate that the 1.83 m (6') arrangement results in a better utilization of the light output. Therefore, the authors recommend the 1.83 m spacing for H.P.S. luminaires.

4. The authors feel that the traditional concepts of uniformity (max/min or average/min) are not too well related to legibility of letters or messages. Therefore, a different concept was introduced: the local relative change or gradient of illumination which is believed to be directly related to the legibility of single letter or symbols. As discussed in chapter 2 and 7 of this report, the gradient uniformity values seem to be more indictive of the actual lighting characteristics than max/min or average/min uniformities. Therefore, the authors would recommend that the present standards of uniformity be supplemented or even replaced by innovative standards of gradients.

5. Further, legibility of messages depends also on contrast, and there is variation of the luminance contrast due to the

colour rendition of the light source. It was discovered that for all color combinations used by MTC, the luminance contrast generally increases when the light source is changed from Mercury to H.P.S. (Table 4). Therefore, H.P.S. is also recommended in terms of luminance contrast from color combinations.

It should be mentioned that the modified contrast formula, introduced in the beginning of this paper, should be used when calculating the contrast level.

6. With regard to illumination level and uniformity, both luminaire types are technically equivalent, especially when the distance between luminaires is optimized as follows:

125 W Mercy Vapor Luminaire	:	2.44 m (8')
70 W HPS Luminaire	:	1.83 m (6')

The High Pressure Sodium luminaires use only about 55% of the energy required for the Mercury Vapor luminaires. Thus, subject to an annualized cost analysis as a final test of overall economy, a change to the High Pressure Sodium luminaire should be recommended.

9/ REFERENCES

1. Lewin, Ian, PR.D., "A Luminance Approach to Highway Sign Lighting", I.E.S. Transaction, Journal of January 1974.

2. Kaufman, J.E., "I.E.S. Lighting Handbook", 5th Edition, 1972.

3. I.E.S. Transaction, Journal of I.E.S./October 1974, "Roadway Sign Illumination".

4. Ministry of Transportation & Communications, "Part 2435-1 of Design Manual", February 1976.

5. Leigh, D.T., "Public Lighting", Illumination of Traffic Signs, The British Standards, London, Gr. Br., December 1976.

6. Transportation Research Record 562, "Measures of Effectiveness, Railroad-Highway Grade Crossing, and Visibility", National Research Council.

7. Transportation Research Record 611, "Railroad-Highway Crossing, Visibility and Human Factors", National Academy of Sciences, Washington, D.C., 1976.

8. DeBoer, J.B., Cohn, M., DeGraaff, A.B., Knudsen, B., Schreuder, D.A., "Public Lighting", N.V. Philips' Glosilamenfabriken, ein dkaven, The Netherlands, 1967.

9. Photo Research Division of Kallmorgan Corporation, "Spectra Pritchard Photometer, Model 1980". Burbank, California, U.S.A.

10. Bureau of Design Services, "Mercury Vapor Sign Lighting", Ohio Division of Highways, June 1974.

Appendix A

Detailed drawing of Sign Board Installation

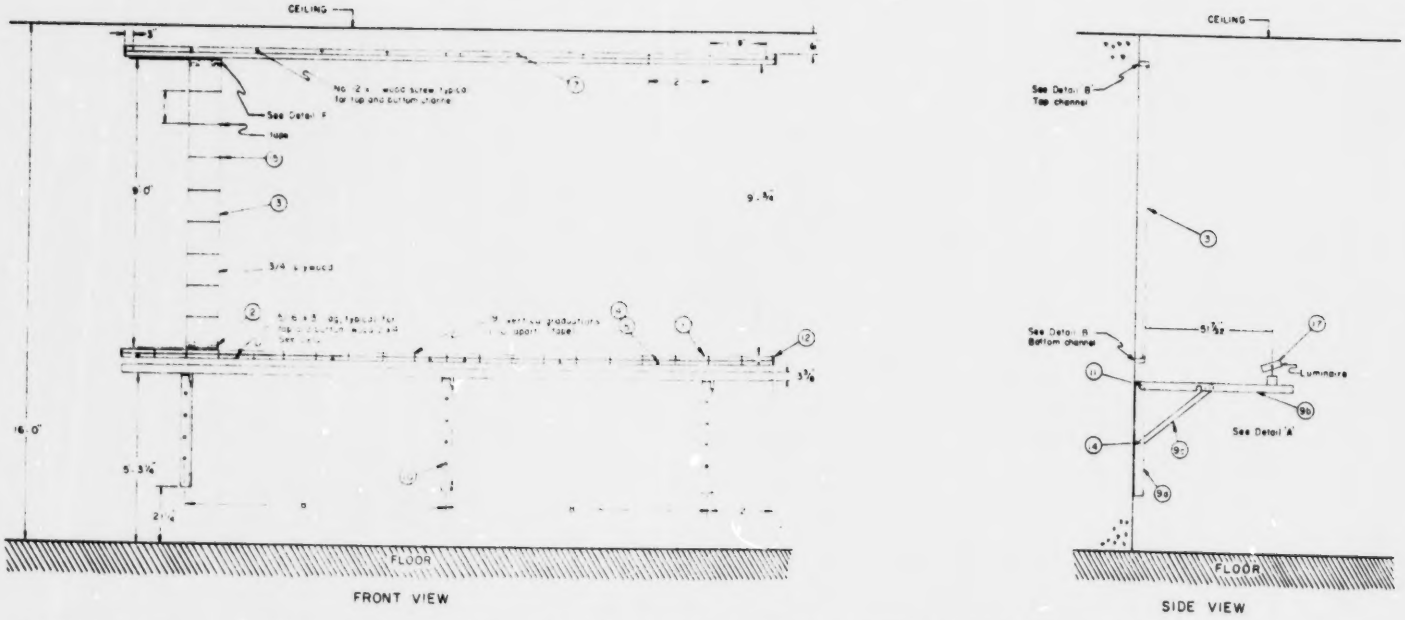


FIGURE A-1 : Detailed Drawing of Simulated Sign Installation Board

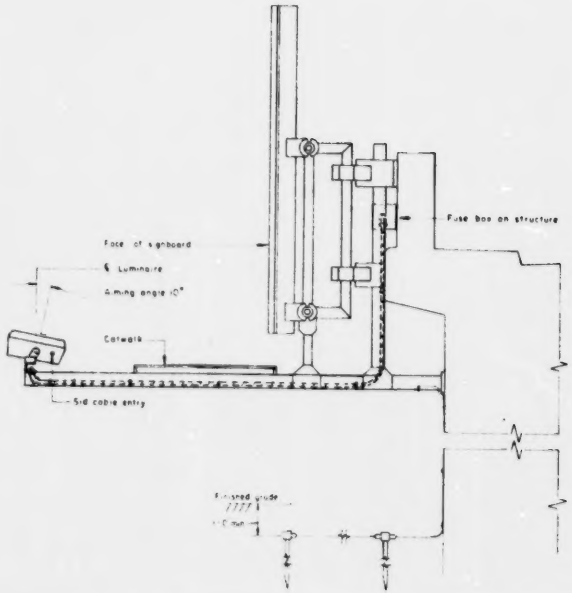


FIGURE A-2 : Sideview of Actual Overhead Sign Installation

Appendix B

Example Computer Output
of
Results and Supplementary Tables

Appendix B - Example Computer Output of Results

A computer program has been developed to analyze the measured data of Illuminance or Luminance and to study and evaluate appropriately the lighting characteristics. Figures B-1 and B-2 represent the output figures of Illuminance and Luminance characteristics respectively, as an example.

Another program has been developed to evaluate the maximum and minimum contrast for different color combinations, according to the formula given on page 5 of this report. Figure B-3 is an example output of contrast calculation for white messages on green background.

Figure B-4 is an example listing of measured Illuminance data at grid points along the simulated sign board plane.

ILLUMINANCE MEASUREMENTS

CHARACTERISTICS OF THIS MEASUREMENT

SIZE OF SIGN BOARD	:	2.74 M. BY 6.10 M. (9 X 20)FEET
NUMBER & TYPE OF LUMINAIRES	:	3 X 70 W. HIGHT PRESSUR SODIUM
DISTANCE BETWEEN LUMINAIRES	:	1.829 M.(6.0 F.) C. TO C.
ANGLE OF LUMINAIRES	:	10.0 DEGREE

LIGHTING STATISTICS ALONG THE SIGN BOARD

AVERAGE ILLUMINANCE	=	220.72 LUX	AVG/MIN UNIFORMITY	=	2.73
MAXIMUM ILLUMINANCE	=	376.74 LUX	MAX/MIN UNIFORMITY	=	4.67
MINIMUM ILLUMINANCE	=	80.73 LUX	* GRADIENT UNIFORMITY	=	9.488

* GRADIENT UNIFORMITY : AVERAGE OF LOCAL RELATIVE GRADIENTS.

POSITION OF THE HIGHEST GRADIENTS ALONG THE SIGN BOARD :

1 ST. MAX.GRADIENT IS:	573.868	BETWEEN POINTS:	(8,13)&(9,13) #
2 ND. MAX.GRADIENT IS:	573.868	BETWEEN POINTS:	(8, 8)&(9, 8)
3 RD. MAX.GRADIENT IS:	565.039	BETWEEN POINTS:	(8,14)&(9,14)
4 TH. MAX.GRADIENT IS:	565.039	BETWEEN POINTS:	(8, 7)&(9, 7)

POINT COORDINATS ALONG SIGN BOARD
GRADIENTS ARE CALCULATED PER UNIT LENGHT "METER".

Figure B-1: Example computer output of Illuminance characteristics

LUMINANCE MEASUREMENTS

CHARACTERISTICS OF THIS MEASUREMENT

SIGN MATERIAL & COLOR	:	GREEN HIGH INTENSITY
SIZE OF SIGN BOARD	:	2.74 M. BY 6.10 M. (9 X 20)FEET
NUMBER & TYPE OF LUMINAIRES	:	3 X 70 W. HIGHT PRESSUR SODIUM
DISTANCE BETWEEN LUMINAIRES	:	1.829 M.(6.0 F.) C. TO C.
ANGLE OF LUMINAIRES	:	10.0 DEGREE

LIGHTING STATISTICS ALONG THE SIGN BOARD

AVERAGE LUMINANCE	=	1.10 CD/M2	AVG/MIN UNIFORMITY	=	3.15
MAXIMUM LUMINANCE	=	2.57 CD/M2	MAX/MIN UNIFORMITY	=	7.34
MINIMUM LUMINANCE	=	0.35 CD/M2	* GRADIENT UNIFORMITY	=	0.537

* GRADIENT UNIFORMITY : AVERAGE OF LOCAL RELATIVE GRADIENTS.

POSITION OF THE HIGHEST GRADIENTS ALONG THE SIGN BOARD :

1 ST. MAX.GRADIENT IS:	3.314	BETWEEN POINTS:	(6,17)&(7,17) #
2 ND. MAX.GRADIENT IS:	3.314	BETWEEN POINTS:	(6, 4)&(7, 4)
3 RD. MAX.GRADIENT IS:	2.920	BETWEEN POINTS:	(6, 5)&(7, 5)
4 TH. MAX.GRADIENT IS:	2.920	BETWEEN POINTS:	(6,16)&(7,16)

POINT COORDINATS ALONG SIGN BOARD
GRADIENTS ARE CALCULATED PER UNIT LENGHT "METER".

Figure B-2: Example computer output of Luminance characteristics

CALCULATED CONTRAST LEVEL ON EXTERNALY ILLUMINATED OVERHEAD SIGNS

1) CHARACTERISTICS OF THE INSTALLATION

SIZE OF SIGNBOARD : 2.74 M. BY 6.10 M. (9 X 20)FEET
NUMBER & TYPE OF LUMINAIRES : 3 X 70 W. HIGHT PRESSUR SODIUM
DISTANCE BETWEEN LUMINAIRES : 1.829 M.(6.0 F.) C. TO C.
ANGLE OF LUMINAIRES SET-UP : 19.0 DEGREE

2) CHARACTERISTICS OF THE BACKGROUND & MESSAGES

	TYPE / COLOUR	BACKGROUND: ENGINEERING GRADE GREEN	MESSAGE: G.WHITE
LUMINANCE (CD/M2)	AVERAGE	1.14	55.04
	MAXIMUM	2.79	97.50
	MINIMUM	0.32	22.39
LUMINANCE UNIFORMITY	AVG/MIN	3.57	2.47
	MAX/MIN	8.72	4.37
	GRADIENT	0.589	0.498

* GRADIENT UNIFORMITY : AVERAGE OF LOCAL RELATIVE GRADIENTS.

3) CALCULATED CONTRAST LEVEL

MAXIMUM CONTRAST = 1.944
MINIMUM CONTRAST = 1.876

Figure B-3: Example computer output of contrast calculation

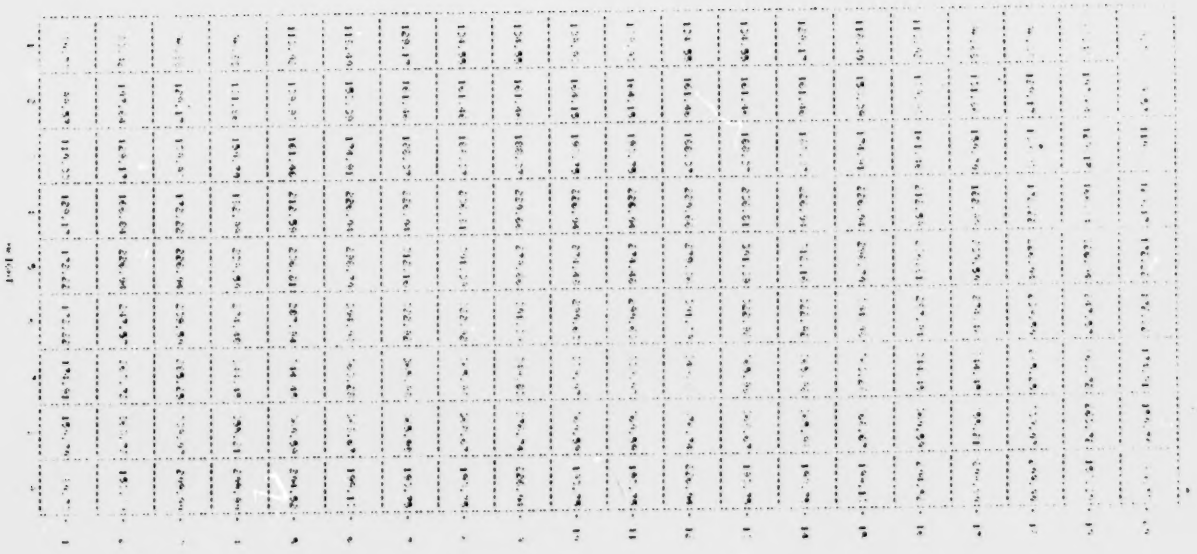


Figure B-4: Example listing of measured Illuminance level at grid points along the sign board plan

List of Figures

Figure 1,	Installation for overhead sign simulation.
Figure 2, (a, b)	Luminaire 2-a, H.P.S. and 2-b, M.V.
Figure 3,	Photometer, for Illuminance Measurements.
Figure 4,	Spectra prichard photometer, for Luminance Measurements.
Figure 5,	Instrument arrangement for Luminance Measurements.
Figure 6,	Light distribution pattern for 125 W M.V. Luminaires with (2.44 m (8') C. to C. distance and 10° angle).
Figure 7,	Light distribution pattern for 125 W M.V. Luminaires with (2.44 m (8') C. to C. distance and 0° angle).
Figure 8,	Light distribution pattern for 125 W M.V. Luminaires with (1.83 m (6') C. to C. distance and 10° angle).
Figure 9,	Light distribution pattern for 70 W H.P.S. Luminaires with (2.43 m (8') C. to C. distance and 10° angle).
Figure 10,	Light distribution pattern for 70 W H.P.S. Luminaires with (1.83 m (6') C. to C. distance and 10° angle).
Figure 11,	Location of the points with Maximum Illuminance Gradients and Magnitude of the related Normalized Gradient Uniformities for Mercury Vapor Luminaires.
Figure 12,	Location of the points with Maximum Illuminance Gradients and Magnitude of the related Normalized Gradient.

List of Figures - Cont'd

Figure A-1, "Appendix A", Detailed Drawing of Sign Board Installation.

Figure A-2, "Appendix A", Side view of actual Overhead Sign Installation

Figure B-1, "Appendix B", Example of Computer Output of Illuminance Characteristics.

Figure B-2, "Appendix B", Example of Computer Output of Luminance Characteristics.

Figure B-3, "Appendix B", Example of Computer Output of Contrast Calculation.

Figure B-4, "Appendix B", Example Listing of the Measured Illuminance Level at Grid Points along the Sign Board Plan.